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the historical record, which of course is the province of paleobotany; and furthermore, that general conclusions based upon the study of the living flora alone are more apt to be false than true.

The great problem of paleobotany to-day is the history of angiosperms. Having perfected a weapon in the attack upon gymnosperms, it remains for the paleobotanist who is a vascular anatomist to uncover the origin of our greatest group, with its comparatively brief history. The origin is probably recorded in the Mesozoic, and we wish to see the significant structures, and not guess at external form, and much less guess at purely hypothetical connections. To this great task paleobotany is turning. We have had the guesses; and I am confident that presently we shall have the facts.

II. THE RELATIONS OF PALEOBOTANY TO BOTANY

2. *Morphology*

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THE morphology of Goethe's metamorphoses, a hundred years ago, was entirely external morphology, illuminating at the time and for many decades later; but now for over a quarter of a century extinct, except so far as it lives on for descriptive purposes in manuals of systematic botany. It has been replaced by a conception of morphology, based not on external form but on internal structure. The replacement has been slow in this country, where, unfortunately, morphology is still very largely a thing of external threads and patches. The father of plant morphology in its modern form, was, as you all know, Wilhelm Hofmeister, who, over fifty years ago, began to put the subject on a truly evolutionary basis. Like many other men of genius, he was before his time and received little appreciation from his less progressive contemporaries.

But it is Professor Coulter's task to deal with morphology, particularly in its paleobotanical aspects, in relation to systematic botany, as is specially fitting, since the laboratories over which he presides at Chicago have up to the present time been the greatest single influence in putting American morphology on a modern and progressive basis. His important relation to systematic development in this country is also well known, representing as it does an earlier but not less striking phase of his botanical activity. My excuse for even referring to systematic matters in these preliminary remarks is the close relation in which they necessarily stand or should stand to morphology and paleobotany. Darwin in his immortal "Origin of Species," although but little given to figurative language, has described morphology as the soul of natural history. It is to be feared that there is just ground for complaint, that the botanical natural historian has in the past too often worn his soul upon his sleeve or has even appeared to lack that necessary adjunct of higher existence. Internal morphology now holds the field and all other lines of botanical activity from systematic botany to plant physiology must take account of its doings, if they are to make solid and enduring progress.

If a change has come in recent years in the point of view of morphology, an equally important shifting of position has taken place, during the past few decades in the attitude of paleobotany. Until the late seventies of the nineteenth century, paleobotany had to do practically with the external form of plants alone, as they appear as impressions in the rocks. It is true that Brongniart in the earlier years of the last century realized the importance of internal structure in the case of fossil plants and, as Dr. Scott has recently pointed out, his views on this subject are so clear and fit actual conditions so well, that they read as if they were written only yesterday. But Brongniart had few followers even among his own countrymen. To the Englishman, Williamson, belongs a large part of the credit of putting paleobotany on a really satisfactory footing. He insisted on the absolute necessity of taking into consideration internal structure as well as external form, and went so far in some of his writings as to state that imprints or impressions alone, of extinct plants, had little scientific value. What may be called the evolutionary bias of Englishmen, a fortunate inheritance from the greatest of all biologists, Charles Darwin, has led them far in the pursuit of paleobotany on anatomical lines. We need only call to mind the demonstration on anatomical grounds that the greater part of the trees of the Coal Period were, in spite of their arboreal habit, in reality vascular cryptogams, a demonstration absolutely confirmed later when it was possible to study, in detail, their reproductive organs. An even more striking illustration of the same kind is supplied by some of the fern-like forms of the Paleozoic, which have long appeared in the catalogue as vascular cryptogams. Here too it was first shown on anatomical grounds, and afterwards from the examination of the organization of the reproductive structures, that outward appearances were entirely deceptive and that the organisms in question were in reality seed plants of a primitive type. These two illustrations, which might be indefinitely multiplied, serve to indicate the very important services which the study of internal organization has rendered both to the natural system and to the doctrine of evolution. They further make it clear that the aphorism of mundane existence, which admonishes us not to trust to appearances, holds equally well in the domain of plants. Paleobotany, like morphology, has accordingly at the present time entered into the anatomical phase of development.

So long as morphology concerned itself mainly with the external form of the reproductive structures of existing plants and paleobotany had perforce to content itself for the most part with the impressions upon the rocks of the foliar organs of extinct ones, there was little to bring these two branches of botanical science together. The systematic botanist was accordingly quite safe in ridiculing the insufficiency of the evidence upon which the conclusions of the older paleobotany was founded. With the advent of the anatomical phase of development in both morphology and paleobotany, the two sciences have become united on the basis of common interests and are both enormously strengthened by the union. Morphology, from being the exponent of *a priori* philosophical ideas, applied to the question of the evolution of plants, and derived for the most part from the inner consciousness rather than from any truly scientific and inductive study of facts, has become the logical fancy-free handmaiden of evolution. Paleobotanical science, on the other hand, having realized, especially in the case of the older plants, which are naturally of the greatest importance from the evolutionary standpoint, that the external form, even the external form of the reproductive structures, is often very deceptive as to real affinities, has come to regard as most important the much less variable internal organization of extinct plants. Paleobotany is in the position to supply us now, for the first time, with reliable facts regarding the organization and true systematic affinities of the ancient vegetation of the earth, and morphology has reached a condition of maturity where facts are infinitely more important than philosophical fancies, however charmingly expressed.

It is unfortunately the case that morphology, until comparatively recently, has been quite as unscientific in its methods as the systematic botany with which in the earlier years of its existence as a branch of botanical science it was intimately allied. The recent important change of attitude in plant morphology is practically entirely due to extensions in our knowledge of the organization of extinct plants. Sachs in the second part of his classic ''History of Botany,'' which deals with plant anatomy and similar matters, deplores this unsatisfactory condition in the following words: ''Owing to the extraordinary diversity of opinion that exists among botanists even on the most general questions in the science, it is extremely difficult to ascertain what can be considered a common possession,—an unfortunate condition of things from which no science suffers perhaps so much as Botany.'' Until comparatively recently these words were as true of plant morphology and plant physiology as when they were written, nearly forty years ago. If there is any mitigation of the situation it is because of the application of chemical and physical laws to the understanding of the functioning of plant structures and the facts of modern paleobotany to the elucidation of the structures themselves. There can be no doubt whatever, that, without the background supplied by our increasing knowledge of fossil plants, the picture painted by the morphologist and embryologist of the evolution of plants is without depth and entirely without perspective. We literally can not see our wood for the countless trees which have crowded into the foreground representing its most modern stage of development. It is certainly impossible to formulate even the rudiments of the evolutionary perspective of plants in the absence of paleobotanical facts as the enduring and fundamental background.

It is accordingly impossible to deny that in the past morphology has been largely fanciful, where it has departed in any way from the bare description of the facts of structure in modern plants, or has attempted to arrange them in accordance with any general or scientific principles. True the situation has been relieved not a little, as a result of the study of development and comparative anatomy, but the difficulty has always been here to decide the direction in which a comparative or developmental series should be read. The indispensable sense of direction can alone be supplied by sighting down the fingerposts of the past, the records of fossil plants, which show us the real path by which evolutionary advancement has been made in any given case.

One of the commonest fallacies of the older morphology was to regard simpler structures as more ancient and complicated ones as more specialized and modern. This error is very deeply implanted in the existing highly artificial systematic arrangement of the higher plants. For example in the case of the conifers, the Taxaceæ are put lower than the Pinaceæ, on account of the simpler organization of their reproductive and vegetative structures. The paleobotanical record, however, shows us clearly that the Pinaceæ, particularly the abietineous Pinaceæ, are among the most ancient representatives of the coniferous stock, while the Taxaceæ, particularly the genus *Taxus,* stand for the class in its most modern condition of development. Let us take another illustration from the Angiosperms. Systematic text-books invariably place the Monocotyledones below the Dicotyledones, on the basis of their simpler organization. This view of the matter does not accord, however, with the results of anatomical and paleobotanical research, which clearly show that the Monocotyledones are neither ancient in their occurrence nor primitive in their organization, but represent a condition of reduction from ancestors which were essentially dicotyledonous in their more important characteristics. These two illustrations, which might be multiplied indefinitely from systematic works, show that the older morphology was essentially fanciful and philosophical in its methods and by no means worthy of the name of an inductive science.

The new morphology, purely inductive in its procedure, is solidly founded on the testimony of the rocks and considers no sequence valid, unless it is clearly supported by the evidence derived from the study of fossil forms. It shows itself moreover scientific in its firm adhesion to valid general principles and its disregard of uncoordinated facts. These general principles too are few in number and are as easily grasped in their simplest form as are the great generalizations of the sister sciences, chemistry, physics and astronomy. The three most important laws or general principles of morphology are those which have to do with recapitulation, reversion and retention. The first is common to both plants and animals, while the other two are infinitely better illustrated by botanical than zoological facts. The validity of these laws has long been admitted in a somewhat hazy and unpractical fashion. It has remained for morphology based on paleobotany to bring them into prominence as the fundamental working principles of the investigator of plant evolution. They are in fact the rudiments, the three R's of biological science, with which even the tyro should become well acquainted.

We can not do better than take a particular illustration of these laws as applied to botanical facts. The conifers show themselves particularly favorable for the elucidation of general evolutionary principles, because they not only constitute a large, varied and widely distributed element of our existing flora, but can be traced, with trifling interruptions, continuously far into the past. Of the conifers there is one tribe at the present time entirely confined to the southern hemisphere. I refer to the Araucariineæ, of which the New Zealand Kauri and the Norfolk Island pine may appropriately stand as examples. In the Mesozoic period, the middle ages of our earth, they flourished throughout the entire world. It is often considered that the Araucariineæ represent the most ancient group of conifers. This belief appears to be based on a too common fallacy, that groups nearly extinct in the existing flora necessarily represent ancient forms. A further basis for the hypothesis of the extreme antiquity of the Araucarian conifers is derived from their habit and the general features of organization of their wood, in both of which respects they present points of resemblance, by no means complete, however, with those Paleozoic gymnosperms to which the origin of the general coniferous class is by common consent of morphologists and paleobotanists referred, namely, the Cordaitales. If we follow the Araucariineæ backward step by step, as recent additions to our knowledge now permit us to do, into the past, we find that although in the Tertiary they retained very largely the characteristics which they present to-day in the Cretaceous, particularly in the Lower Cretaceous and in the Jurassic, they become less and less like their existing representatives and more and more like the Abietineæ, the actually dominant conifers of the northern hemisphere, both in general organization and wood-structure. To save time let us consider only three points of anatomical organization, for comparison. The existing Araucariineæ are remarkable among conifers and gymnosperms generally, in possessing leaf-traces which continue to be formed in the wood by the cambium, long after the leaves which they originally supplied have ceased to exist. The old trunk of a *Kauri* or an *Araucaria,* for example, shows on the outside of its wood marks representing the traces of leaves, which may have disappeared hundreds of years previously. This feature has been seized upon by Professor Seward as one of undoubted primitiveness. It is certainly bizarre, and if one accepts the unusual as the criterion of antiquity, the Araucariineæ certainly could qualify for an ancient lineage on this character. This view does not however accord with paleobotanical facts. In the Lower Cretaceous we find very many undoubted Araucarian trunks, in which the leaf-traces were not persistent as in the existing representatives of the tribe and in the Jurassic and Triassic trunks of this type become practically universal. This at once makes it clear that the persistent leaf-trace, so characteristic of the living *Kauri* and *Araucaria,* is not an ancestral feature of the Araucarian stock. Recently we have sent out from Harvard a botanical expedition to Australasia. At my suggestion Messrs. Eames and Sinnott, who were its personnel, have brought back old seedlings of the two existing Araucarian genera. On investigation of the lower region of these in proximity to the cotyledons, it was found that here the leaf-traces were ephemeral in their persistence, exactly as in the older Mesozoic representatives of the Araucarian stock from the Lower Cretaceous, Jurassic and Triassic deposits. Here appears a very striking example of the validity of the law of recapitulation as exemplified by the young individual, the seedling stem for a short part of its vertical length repeating ancestral conditions which have long disappeared in the adult. Let us consider two remaining characters together, in order to economize time. The water pores of the tracheids in existing Araucarian conifers occur in a crowded and alternating condition and are deformed or flattened by mutual contact, a feature of resemblance to the oldest known gymnosperms. This feature is in marked contrast to the pit arrangements of the other existing tribes of conifers, where the water pores are loosely grouped and when numerous and multiseriate are opposite. Another unusual feature of the wood of existing Araucariineæ is the absence of wood parenchyma, a feature likewise illustrated by the woods of the Paleozoic gymnosperms. If we follow the Araucarian conifers below the horizon of the present, we observe in the older representatives a condition of pitting of the tracheids, which the lower we go geologically, becomes more and more like that found in the other tribes of conifers, particularly the Abietineæ, so much so that Gothan, who has recently described the Jurassic woods of Spitzbergen and other arctic islands, which in the Mesozoic supported a luxuriant flora, has identified them as of Abietineous affinities. It is further found in the case of those Mesozoic fossil woods which most nearly resemble the living genera *Agathis* and *Araucaria,* that wood parenchyma was exceedingly abundant. Now let us examine our Araucarian seedlings in regard to these features. The wood of the cotyledonary region here exemplifies both the characteristic pitting and presence of wood parenchyma of the Mesozoic *Araucarioxylon* type. Thus the Araucariineæ, which we are able to follow very far back into the past, present a very striking illustration of the biological law of recapitulation. Other features of the seedling might have been considered with the same result.

But ancestral conditions are not in plants confined to the young individual. We find them also illustrated in connection with the principles of retention and reversion. The law of retention is well exemplified by the root, cone and first vegetative annual ring of the Araucariineæ, where the Mesozoic features of structure appear only less completely than they do in the seedling. The law of reversion is likewise illustrated readily in this tribe of conifers in connection with injuries, for the wood formed subsequently to wounds shows Mesozoic characters, which are not a feature of normal structure.

It appears clear from the illustration which I have chosen, only one among many possible ones from the results of recent coordinated anatomical, developmental, experimental and paleobotanical investigations, that we have definite laws of plant evolution. It is further clear that like Ulysses we must "follow knowledge like a sinking star" into the night of the past, if we are to reach durable general biological principles. The laws of recapitulation, retention and reversion, founded on cases where it is possible to trace an unbroken sequence of forms, are likewise applicable to the elucidation of conditions in groups the past of which is as yet insufficiently known. A very notable example of this kind is presented by the Angiosperms. Here more than anywhere else among the higher plants philosophical views in regard to evolution prevail. You are doubtless all familiar with the generally accepted dictum, forming a feature of all elementary botanical instruction, that the woody stem of perennial Dicotyledones is derived from one of herbaceous texture. This conclusion is based on the old fallacy, that simpler conditions are necessarily antecedent to more complex ones and antedate them in time. If we investigate the primitive type of stem organization in the Dicotyledones, in accordance with the principles of recapitulation, retention and reversion, we arrive at very different conclusions indeed and of much greater significance from the standpoint of evolution.

It will save time to take a concrete illustration. In the cross section of a small branch of the oak we find the woody part of the stem, composed of ten alternatingly outstanding and depressed segments, separated from one another by ten large so-called primary medullary rays. In accordance with the herbaceous hypothesis of the origin of the woody stem, the projecting segments are supposed to correspond to five originally entirely separate bundles. Further the intervening depressed segments of the cylinder, set off from the others by the ten large rays, are supposed to represent parts of the wood which have been secondarily interpolated through the activity of a so-called interfascicular cambium. If we examine the facts in the light of the general principles of plant evolution, a very different and much sounder conclusion is reached. Let us take only the seedling evidence, for the other accords absolutely with it. In the cotyledonary region of the young stem we find for a number of years a completely continuous woody cylinder, without either large rays or depressed segments. At this level in fact the rays are entirely narrow ones of the gymnospermous type. Both the broad rays and the segments which they delimit appear only later. The so-called large primary rays are in fact formed as a result of the fusion of smaller rays into aggregates around the incoming leaf-traces. The broad rays of the oak are consequently fusion products and not at all primitive structures. They are clearly related as a storage device for the strands which enter the stem from the leaves. There are two broad rays to each leaf, corresponding to its two strongly developed lateral traces, and since the phyllotaxy of the oak is of the 2/5 type, there are normally and originally five pairs of large rays in the stem. The depression of five of the segments delimited by the large leaf or foliar rays below the level of their fellows presents another interesting problem in evolution, into which there is not time to enter at present. It is enough to say that the so-called primary or large rays of dicotyledonous stems are not primary or primitive structures at all, but are of secondary origin and formed from what was originally wood, in order that the assimilates from the leaves may more readily and conveniently be stored for future use. We have thus an explanation of the relation of the woody to the herbaceous stem, which is at once in harmony with the general principles of plant evolution and at the same time with physiological necessities. The fallacy of considering the herbaceous as the primitive type is further made clear. There is in fact every reason to believe that the early Dicotyledones were entirely woody perennials, just as the forbears of the existing herbaceous Pteridophyta have been shown by paleobotanical and anatomical investigations to have been derived from arboreal ancestors of the Paleozoic.

The clear realization of the universal validity of the primary laws of plant evolution depends almost entirely on our increased knowledge of the organization of fossil plants. There has come to morphology as a consequence of the study of ancient forms a new birth, quite comparable to the remarkable intellectual awakening in Europe, at the beginning of the modern period, resulting from the rediscovery of the ancient classics of the Greeks and Romans. This awakening, known as the renaissance, has its exact counterpart in plant morphology and our enthusiasm over the discovery of new fossil remains which throw a light on the origin of existing plants is not different from that experienced by the enlightened citizens of the Italian cities at the end of the middle ages, over the unearthing of a new manuscript of Virgil or of Horace. As a result of this impetus the morphologist has already in the past decade revolutionized the systematic arrangement of the Gymnosperms and the work in this special field has scarcely begun. In the case of the

Angiosperms, change is also in the air and I venture to predict that within two or three decades at most we shall have made substantial progress towards a scientific, that is, a natural, classification, of what is at present a huge and hopelessly confused labyrinth, penetrated at best in a halting way by the tenuous and insecure thread of our present highly artificial system.

The future presents many interesting possibilities for the morphologist and the paleobotanist and let us hope for the systematist as well. Obviously we are now on the threshold of the discovery of a system of plants which shall depict their evolutionary sequence. Would that we might count on the sympathetic cooperation of all systematic botanists in this stupendous and intellectually attractive task. Unfortunately in the thirties of the last century systematic botany parted company with plant morphology and has appeared since somewhat to resemble the man with the muckrake in the vision of the immortal tinker. Although there hangs above it the shining diadem of a natural system, with which to crown its arduous labors of many years, the raking together of straws, sticks and even antique dust seems to present an invincible attraction. The assiduous strokes of the rake may glean additional straws and sticks; but although we may all agree that he is a benefactor of mankind who makes two living blades of grass sprout where there was one before, we shall scarcely consent with unanimity that the making of more new species out of old ones, is a highly commendable scientific occupation. A great danger on the systematic side appears at the present time to inhere in the doings of so-called world congresses. Recently the paleobotanists of those countries which are mainly active in the investigation of fossil plants have agreed unanimously and publicly to repudiate the vote of the recent congress at Brussels, imposing upon them Latin diagnoses of extinct plants. The students of fossil plants, although they have to do with organisms no longer living, regard their science as a live one and are consequently strongly unwilling to shroud its doings in the pall of a dead language, perhaps not the less because the mandate to do so comes as the result of a Russian ukase. The present world congresses of botanists seem to present certain ominous resemblances to the world councils of the church about the time of the Reformation in Europe. The so-called ecumenical councils of Christianity were unfortunately characterized at that time by reactionary tendencies, including among others a preference for the Holy Writ in the Latin rendering of the Vulgate. Unless there is some relaxation of the mediæval attitude upon the part of the majority of systematic botanists, there is reason to fear a reformation in botany, as uncontrollable as that led by Martin Luther and John Knox in religion. It is sometimes said in favor of Latin diagnoses of plants, that the older literature of systematic botany is in the Latin tongue. The same is true of the equally venerable sciences of chemistry and astronomy, yet for that reason the chemists and astronomers of to-day do not think it necessary to perpetuate the written language of the alchemists and astrologers. Botany has likewise, let up hope, passed through what corresponds to the alchemistical and astrological phase of development and need not conceal its doings in the dog Latin of a Paracelsus or an Albertus Magnus. Conditions in this country are hopeful in this respect, for although we are not wholly free from the pedantry that maketh and loveth a Latin diagnosis, the large majority of American systematists are entirely progressive in their point of view. May they prevail and in the course of time, with all modesty, impress their attitude on the European cultivators of this important field of botanical activity.